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Comparison between boost and positive output super lift Luo converters to improve the performance of photovoltaic system

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ABSTRACT

Employment DC-DC switching power converters in many different areas become is very important. In this paper, three different models of the photovoltaic solar module were proposed in order to designing, implementation, and simulated them in MATLAB/Simulink with the boost converter circuit first and then with the positive output super lift Luo (POSLL) converter circuit again. A comparison was made between the two circuits, as well as a theoretical and simulation values were made and compared between them (in the same standard conditions) for each of these selected models. So as to improving solar system performance and clarify the functions played by POSLL in power electronic circuits.

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1. INTRODUCTION

The power that is generated from solar emission is one significant and worthy sources of renewable energy. This makes it a good option for power because it emits little to no CO_2 and produces clean, inexhaustible energy [1]. The conversion process of sunlight into electrical power is known as a photovoltaic (PV) system [2]. The PV system basic device is known as a PV cell. Modules are bigger units that may be formed by grouping together cells, are then used to create panels or arrays [3]. That are arranged in series-parallel connections and gives voltage ranging 12 to 48 V [4]. A PV module's output properties are influenced by radiation from the sun, temperature of a cell, and the voltage output to the PV module [5]. To process the power from the PV system and to achieved as possible the required voltage, many complicated applications call for a DC-DC electronic converter [6]. These converters are responsible for dominance the power flux at grid-linked systems, for tracking the equipment's maximum power point (MPP), and fundamentally to deal with regulating the average output voltage to the appropriate load voltage. So, it serves as an interface between PV and a loading [3], same due to the fact that two DC_s sources can be powered from either direction by a DC-DC converter [7]. Many of scientific literature reviews have shown the importance of using a DC-DC convertes in electronic power circuits. Including them, Hasaneen and Mohammedin [8] presents examine boost converter equations and suggest design elements and simulation of DC-DC boost converter. Nath and Pradeep [9] proposed the implementation a type of DC-DC converter is called improved positive output super-lift Luo converter (IPOSLC) with the solar panel which enhances the positive output voltage in geometric terms. The major goals for this paper: is to select a three different models of PV solar module and simulate them in the MATLAB/Simulink program with the boost converter circuit and the positive output super lift Luo (POSLL) circuit again. The electrical properties, current and voltage (I-V) and

P-V properties, and design of simulation diagrams for each of these three models were approached. Then, a comparison has been made between the theoretical and simulation results to the output of voltage and current (in the same switching frequency and load) for both two converters and a comparison between them, in order to prove the advantages of POSLL that it enjoys from better performance in electronic power circuits, increasing the output of voltage, decreasing the ripple in output of voltage and current. The comparison demonstrated that the POSLL circuit raises the output voltage higher than boost circuit. This paper attends a summarized introduction to the behavior of two separate power circuits: boost and POSLL converters and write its basic equations. Section 2 defines boost converter and describe a circuit diagram of it. Section 3 defines POSLL and covers elementary circuit and modes operation. Section 4 show a three proposed solar PV module models and review the electrical properties of them. Simulation of PV modules proposed with boost and POSLL converters and simulation results are clarify in detail at sections 5 and 6 respectively. The end was with conclusion in section 7.

2. THE PROPOSED APPROACH

2.1. Boost converter

Boost converter is a device that works in CICM (continuous input current mode) or DICM (discontinuous input current mode), and it’s considered a DC-to-DC voltage converter that raises the input voltage's magnitude to the desired output voltage's magnitude [10], [11]. So, there are two modes that a boost converter can operate:in a charging mode that occurs when the switch is closed and in discharging mode which is known when the switch is open [12]. It’s created from rearranged of a three elements switch (S), inductor (L), and diode (D) of buck converter. It employs: inductor (L), capacitor (C), and at least two semiconductors’ switches, the diode which acts as a freewheeling diode and MOSFET (metal-oxide-semiconductor field-effect transistor) [13], [14]. The circuit diagram shown in Figure 1.

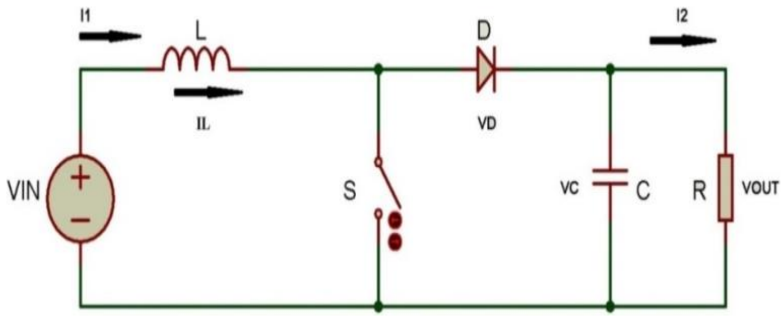


Figure 1. Circuit diagram of a boost converter

2.2. Positive output super lift Luo converter

Luo-converters with super-lift are widely used in power electronic circuits and devices in order to enhance the solar system's performance, for decrease the drawbacks of the ripples in output voltage and current [15], having high efficiency, very high voltage boosted about 3 to 4 times, and cheap topology in simple configuration [16]. Luo converter is working in the voltage lift (VL) technique [17], [18] and executes a voltage exchange from positive input of voltage to positive output of voltage. This converter's transfer gain rises geometrically and incrementally at each level [19]. Basically, it contains of two series, the fundamental series and the supplemental series. One switch (S), n inductors, $2n$ capacitors, and $(3n-1)$ diodes makes up the fundamental series, it also has 2 lifts, 4 lift, and 8 lift Luo converters. supplemental series consist 3 lift, 6 lift, and 12 lift, they also have one switch (S), n inductors, $2(n+1)$ capacitors, and $(3n+1)$ diodes [20], [21].

2.3. Elementary circuit of POSLL converter

By raising the voltage transmission gain over time, Super-Lift LUO converters have demonstrated to be efficient in situations requiring a high output voltage [22]. A POSLL converter usually operates in continuous conduction mode (CCM) with a positive output terminal voltage.The elementary circuit consist of a DC voltage (V_{in}), inductor (L_1), capacitors (C_1 & C_2), freewheeling diodes (D_1& D_2), power switch MOSFET n-channel (S), and resistance (R) [23], [24] as shown in Figure 2.

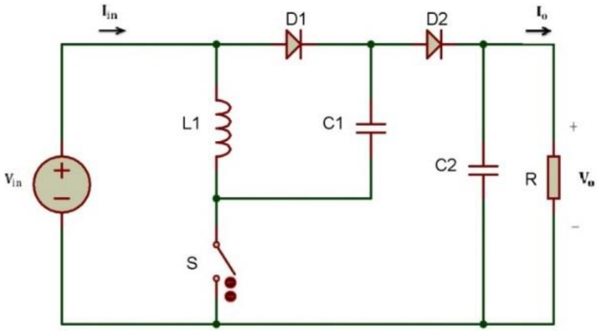


Figure 2. Circuit diagram of POSLL converter

2.4. Modes operation

Due to the parallel connection between inductor L and capacitor C_1 , both of which are charged, and when the switch's ON period (KT), the voltage across capacitor C_1 is charged to V_{in} [23]. The inductor current i_{l1} will increase with voltage V_{in}, capacitor C_2 supplies the load. Freewheeling diode D_1 is in operation and D_2 is Off, as shown in Figure 3(a). The inductor current i_{l1} decreases with voltage (*Vo*-2*Vin*), when the switch is in the OF period (1-K) T, and capacitor C_2 charges. Freewheeling diode D_2 is in operation as shown in Figure 3(b). The ripple of the inductor current i_{l1} [25], [26] is:

$$\Delta i_{l1} = \frac{Vin*K*T}{L_1} = \frac{V_o - 2Vin(1-K)T}{L_1} \tag{1}$$

the input current i_{in} is equal to:

$$I_{(in-on)} = I_{(l_1-on)} + I_{(C_1-on)}$$

$$I_{(in-off)} = I_{(l_1-off)} = I_{(C_1-off)}$$

$$KTi_{(C_1-on)} = (1-K)Ti_{(C_1-off)}$$

the transfer gains in voltage:

$$G = \frac{V_o}{V_{in}} = \left(\frac{2-K}{1-K}\right) \tag{2}$$

as a function of the input voltage, the following (3) and (4) the output voltage:

$$V_o = \left(\frac{2-K}{1-K}\right) Vin \tag{3}$$

$$K = \frac{2Vin-V_o}{Vin-V_o} \tag{4}$$

the inductance $L_1$is by:

$$L_1 = \frac{V_o - 2Vin}{\Delta i_{l1}} * \frac{(1-K)}{f_s} \tag{5}$$

the same formula yields the capacitances C1 and C2:

$$C_1 = C_2 = \frac{(1-K)}{f_s \Delta v_o} * \frac{V_o}{R_o} \tag{6}$$

where *R* is the resistance. Where: I_o is the current of output, Δi_o the ripple current of inductor (peak-to-peak current), Δv_o the ripple in the voltage output and f_s is the switching frequency.

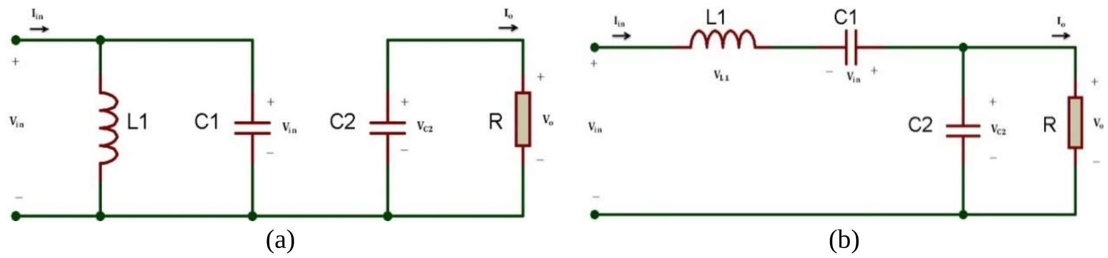


Figure 3. Equivalent circuit for (a) switching-on and (b) switching-off of POSLL converter

3. PROPOSED MODULES OF PV SYSTEMS

The following three models of PV solar module have been proposed with boost and POSLL converters: i) global solar energy FG-2BTM-82 PV module; ii) Luxor solar solo line 140 M PV module; and iii) Kyocera solar KC200GT PV module. These models are thin film, mono crystalline, and multi crystalline types. They were simulated based on its conventional equations and electrical properties of the modules (I_{sc}, V_{oc}), and the input Voltage (V_{max}), by utilization signal generator pulse width modulation (PWM), at conditions temperature 25 ^{0}C, and irradiation 1000 W/m^2. The Tables 1-3 show the key electrical properties for three models at standard conditions.

Table 1. Electrical properties of global solar energy FG-2BTM-82 model

Electrical Properties	Values
Current at maximum I_{mp}	5.3 A
Voltage at maximum V_{mp}	15.5 V
The short of circuit current I_{sc}	6.2 A
The open of circuit voltage V_{oc}	20.9 V
Power at maximum	82.15 W
Number of cells per module (Ncell)	36

Table 2. Electrical properties of Luxor solar solo line 140 M model

Electrical Properties	Values
Current at maximum I_{mp}	8.01 A
Voltage at maximum V_{mp}	17.48 V
The short of circuit current I_{sc}	8.97 A
The open of circuit voltage V_{oc}	22.57 V
Power at maximum	140 W
Number of cells per module (Ncell)	36

Table 3. Electrical properties of Kyocera solar KC200GT model

Electrical Properties	Values
Current at maximum I_{mp}	7.61 A
Voltage at maximum V_{mp}	26.3 V
The short of circuit current I_{sc}	8.21 A
The open of circuit voltage V_{oc}	32.9 V
Power at maximum	200.14 W
Number of cells per module (Ncell)	36

4. SIMULATION OF PV MODULE WITH PROPOSED BOOST AND POSLL CONVERTERS

The design of simulation diagrams of three PV solar module models were implemented using a MATLAB program in MATLAB/Simulink, which is determines the output of current I_o and output of voltage V_o, as shown in Figures 4-9 for boost and POSLL converter circuits respectively.

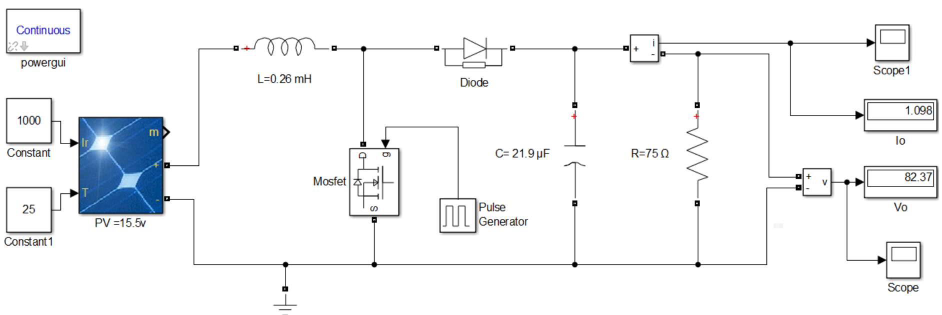


Figure 4. Simulation diagram of boost converter at first model

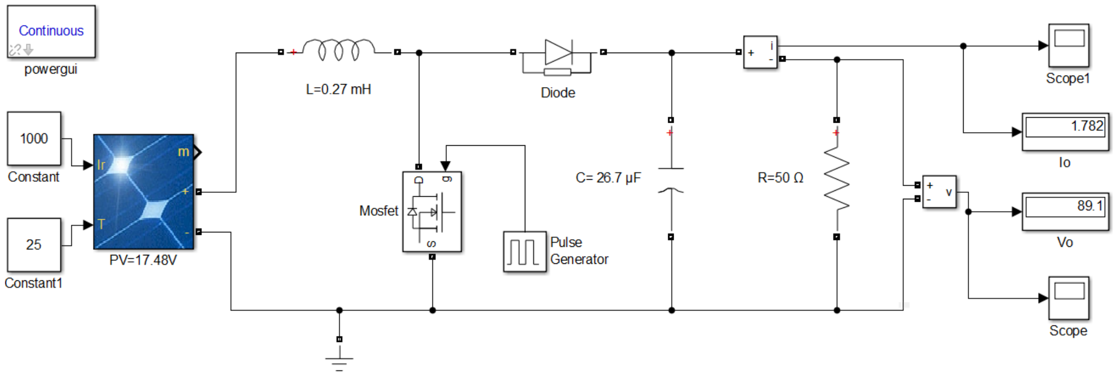


Figure 5. Simulation diagram of boost converter at second model

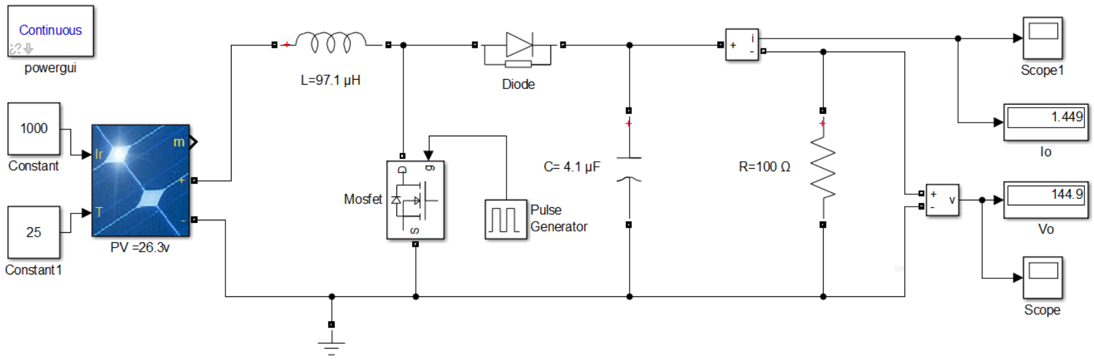


Figure 6. Simulation diagram of boost converter at third model

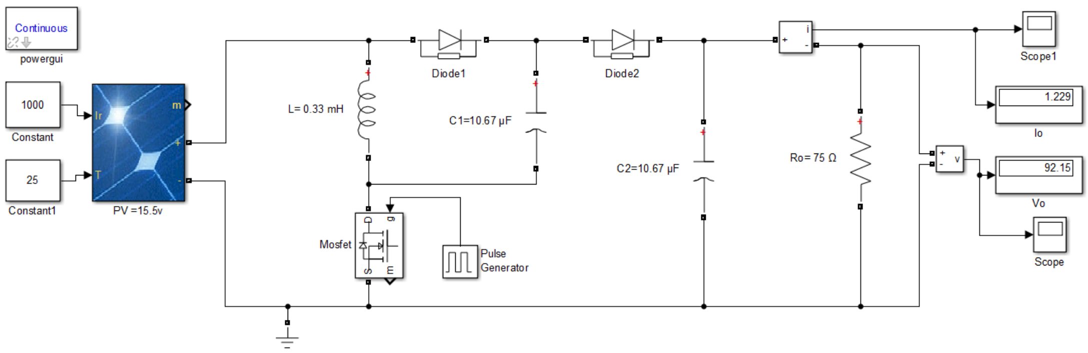


Figure 7. Simulation diagram of POSLL converter at first model

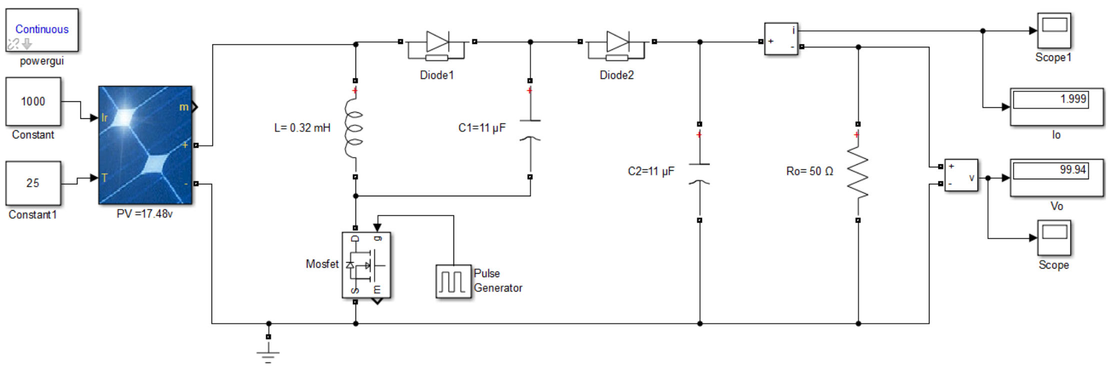


Figure 8. Simulation diagram of POSLL converter at second model

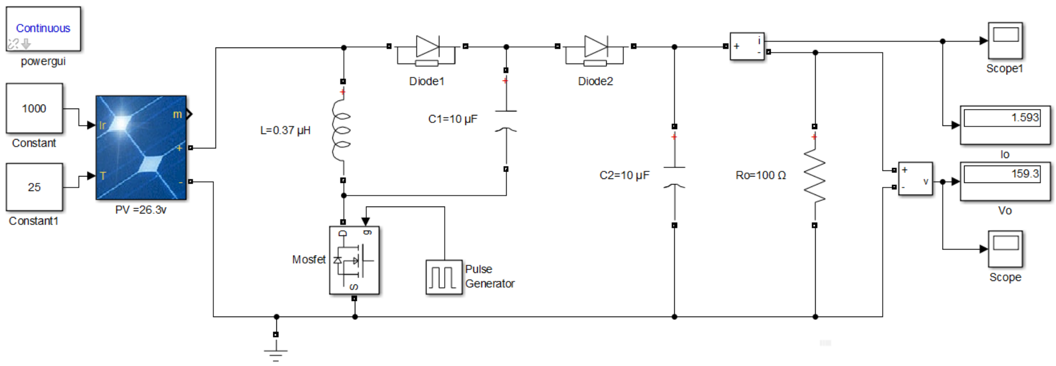


Figure 9. Simulation diagram of POSLL converter at third model

5. RESULTS AND DISCUSSION

The calculation parameters of boost simulation diagrams were designing theoritically according to its equations. Also, of POSLL simulation diagrams designing according to equations (1-5), Figures 10-12 show the output I-V and P-V properties for a three models PV solar module. The ripple current ΔI_l through the inductor ranging from (20% to 40%) and the output voltage ripple is about (1% to 50%). Then, the values of the design parameters are shown in the Tables 4 and 5. In order to valditing the Simulink designs and calculation results computer characteristics (windows 7 HP, Intel(R) Core(TM) i3-2330M processor, installed memory 4.00 GB RAM SSD, and system type 64-bit operating system) with MATLAB 2016 program are employed for boost and POSLL simulation diagrams, to drawn the output of voltage and current waveforms for three models in Figures 13-15 with boost circuit, Figures 16-18 with POSLL circuit as shown in:

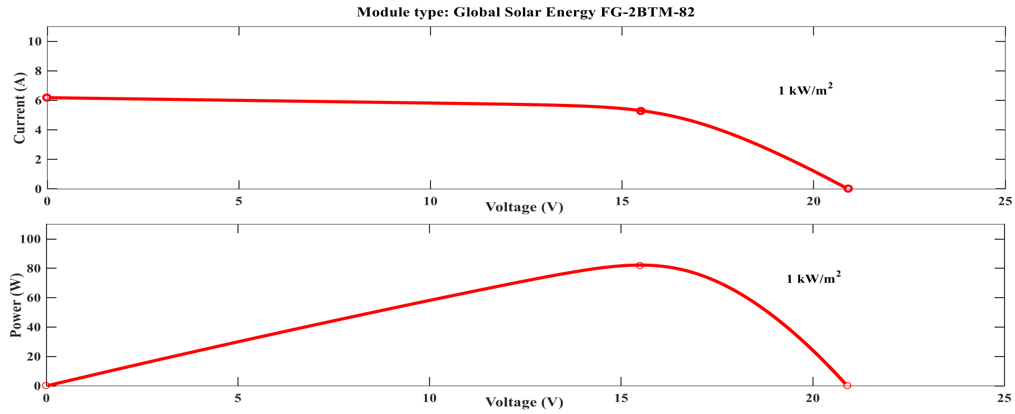


Figure 10. I-V and P-V properties by reference to voltage at first model

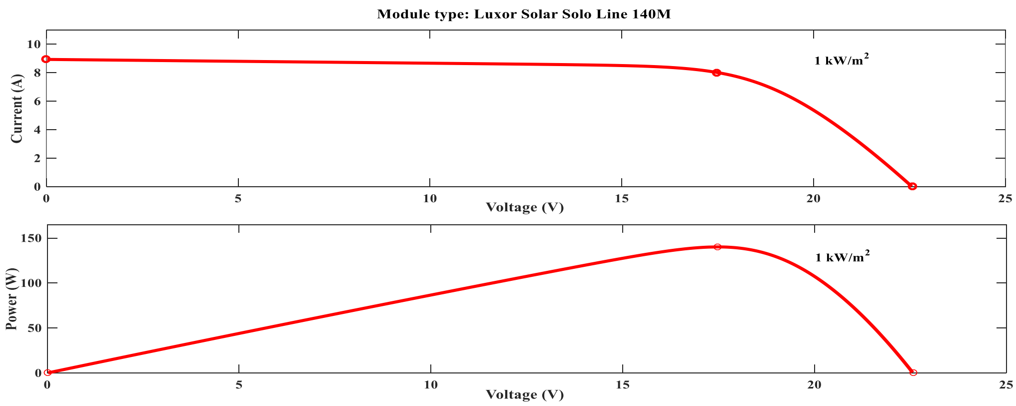


Figure 11. I-V and P-V properties by reference to voltage at second model

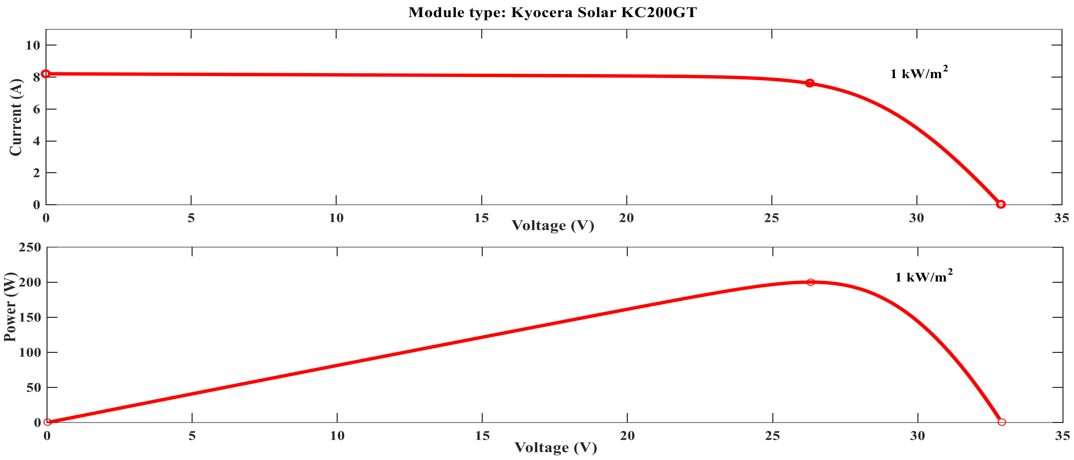


Figure 12. I-V and P-V properties by reference to voltage at third model

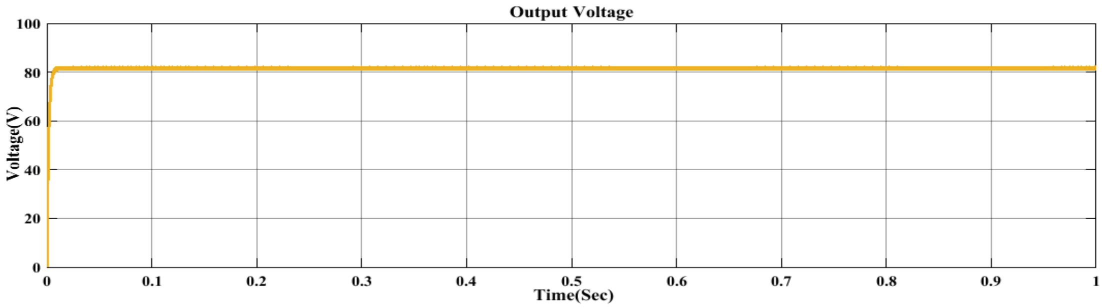
Table 4. The design parameters for boost converter at three PV model

Type of PV Model	Parameters	Theoritical Values	Simulation Values
Global Solar Energy FG-2BTM-82 module	Input voltage	15.5 V	15.5 V
	Output voltage	86.11 V	82.37 V
	Duty cycle	82%	82%
	Inductor	0.26 mH	0.26 mH
	Capacitor1 & Capacitor2	21.9 µF	21.9 µF
	Resistive load	75 Ω	75 Ω
	Switching frequency	25 KHz	25 KHz
Luxor Solar Solo Line 140M module	Input voltage	17.48 V	17.48 V
	Output voltage	87.4 V	89.1 V
	Duty cycle	80%	80%
	Inductor	0.27 mH	0.27 mH
	Capacitor1 and Capacitor	2 26.7 µF	26.7 µF
	Resistive load	50 Ω	50 Ω
	Switching frequency	20 KHz	20 KHz
Kyocera Solar KC200GT MODUL	Input voltage	26.3 V	26.3V
	Output voltage	146.11 V	144.9 V
	Duty cycle	82 %	82%
	Inductor	97.1 µH	97.1 µH
	Capacitor1 and Capacitor2	4.1 µF	4.1 µF
	Resistive load	100 Ω	100 Ω
	Switching frequency	100 KHz	100 KHz

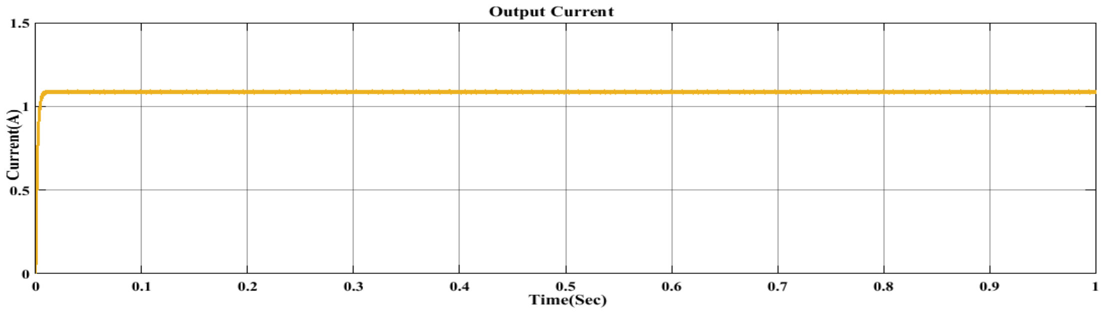
Table 5. The design parameters for POSLL converter at three PV models

Type of PV Model	Parameters	Theoritical Values	Simulation Values
Global Solar Energy FG-2BTM-82 module	Input voltage	15.5 V	15.5 V
	Output voltage	93 V	92.15 V
	Duty cycle	80%	80%
	Inductor	0.33 mH	0.33 mH
	Capacitor1 and Capacitor2	10.67 µF	10.67 µF
	Resistive load	75 Ω	75 Ω
	Switching frequency	25 KHz	25 KHz
Luxor Solar Solo Line 140M module	Input voltage	17.48 V	17.48 V
	Output voltage	96.9 V	99.94 V
	Duty cycle	78%	78%
	Inductor	0.32 mH	0.32 mH
	Capacitor1 and Capacitor2	11 µF	11 µF
	Resistive load	50 Ω	50 Ω
	Switching frequency	20 KHz	20 KHz
Kyocera Solar KC200GT MODUL	Input voltage	26.3 V	26.3 V
	Output voltage	157.8 V	159.3 V
	Duty cycle	80 %	80%
	Nductor	0.37 mH	0.37 mH
	Capacitor1 and Capacitor2	10 µF	10 µF
	Resistive load	100 Ω	100 Ω
	Switching frequency	100 KHz	100 KHz

Figures 13 to 15 also Figures 16to 18 explain the waveforms of: (a) outputs voltage and (b) outputs current for two circuits, as show above in Table 4 where boost circuit, the outputs of voltage are boosted to a certain percentage with some ripples of three PV solar module models. While in case the POSLL circuits the outputs of voltage are raised to a high value with less ripples as shown in Table 5.

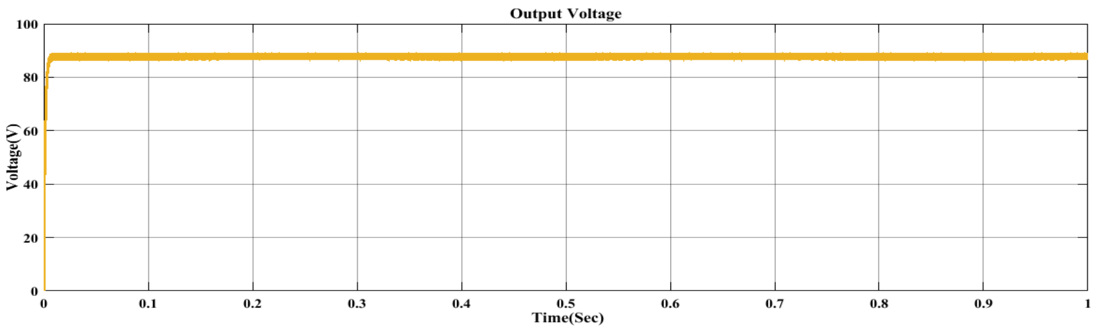


(a)

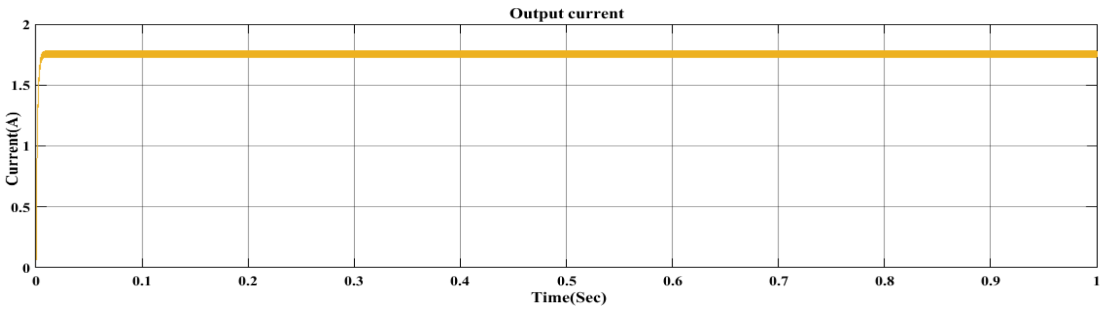


(b)

Figure 13. Simulation waveforms for (a) the output of voltage and (b) the output of current for the boost circuit at first model



(a)



(b)

Figure 14. Simulation waveforms for (a) the output of voltage and (b) the output of current for the boost circuit at second model

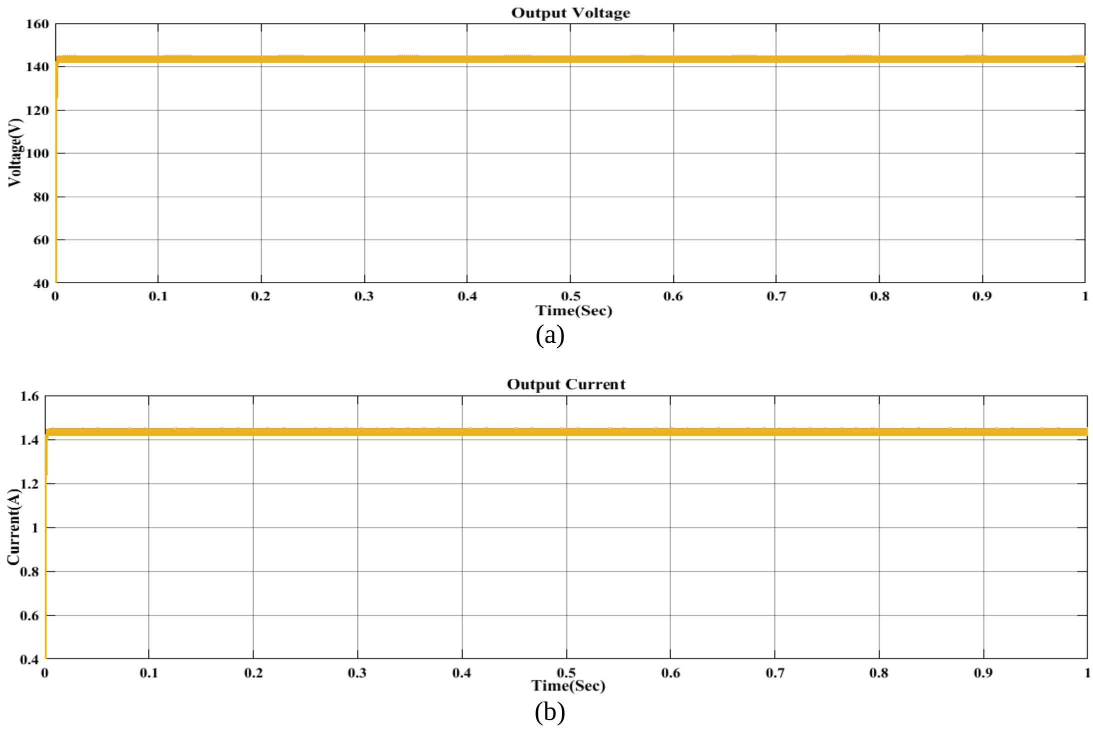


Figure 15. Simulation waveforms for (a) the output of voltage and (b) the output of current for the boost circuit at third model

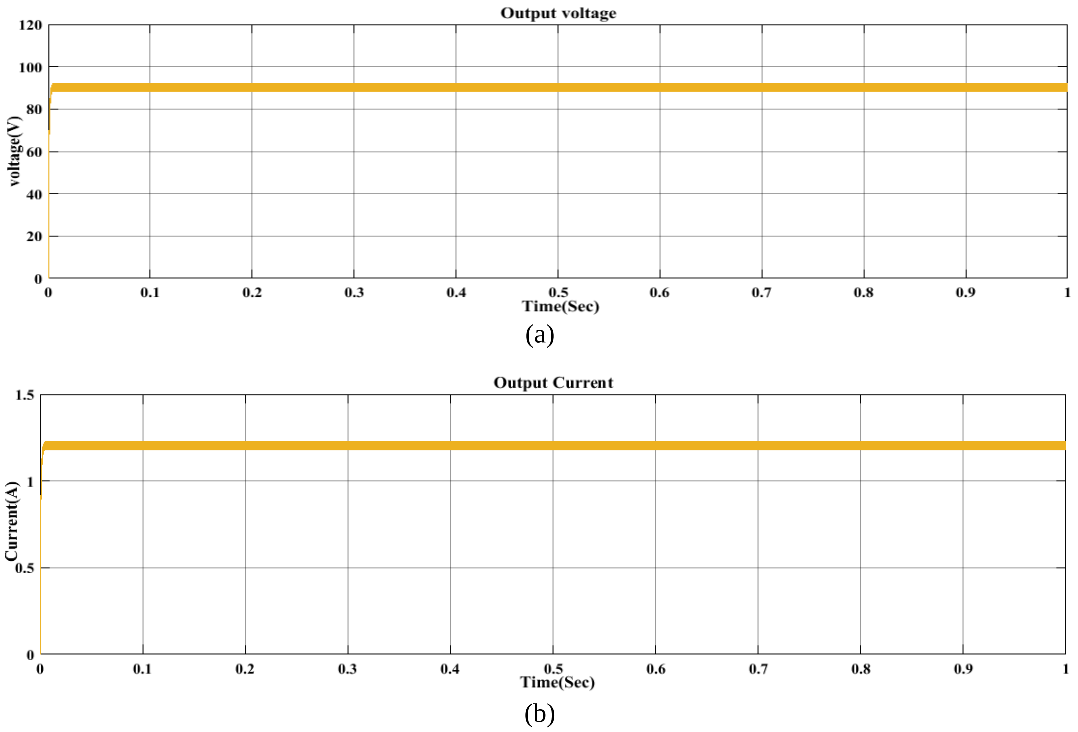
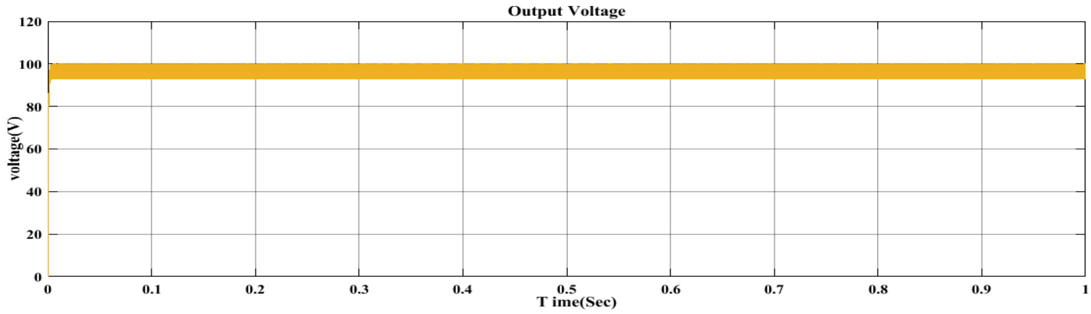
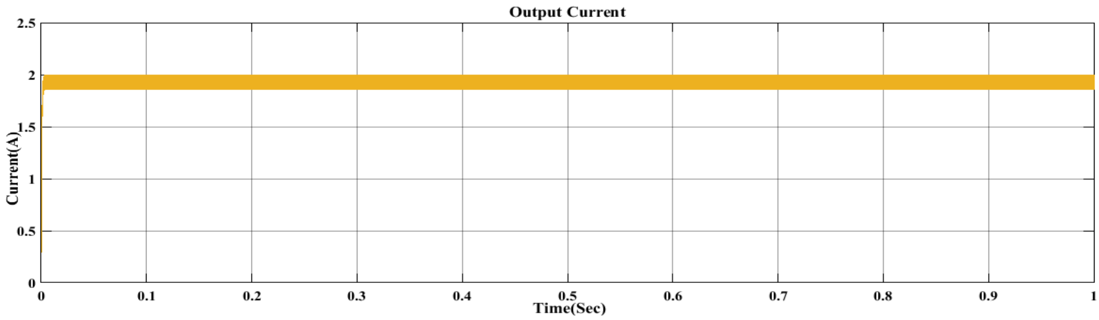


Figure 16. Simulation waveforms for (a) the output of voltage and (b) the output of current for the POSLL circuit at first model

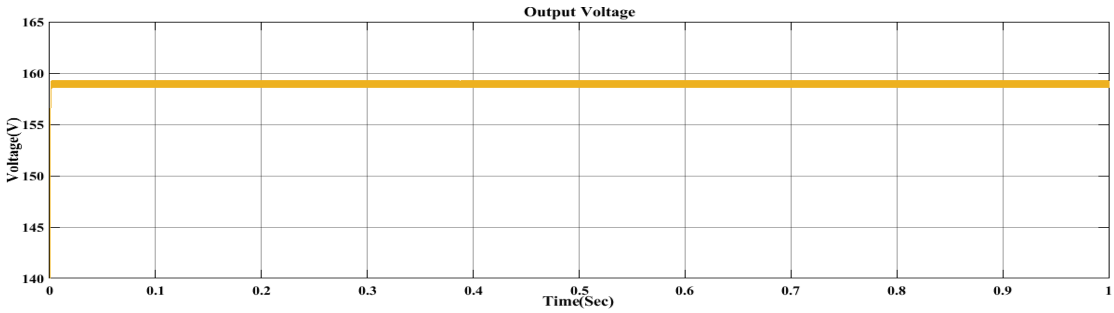


(a)

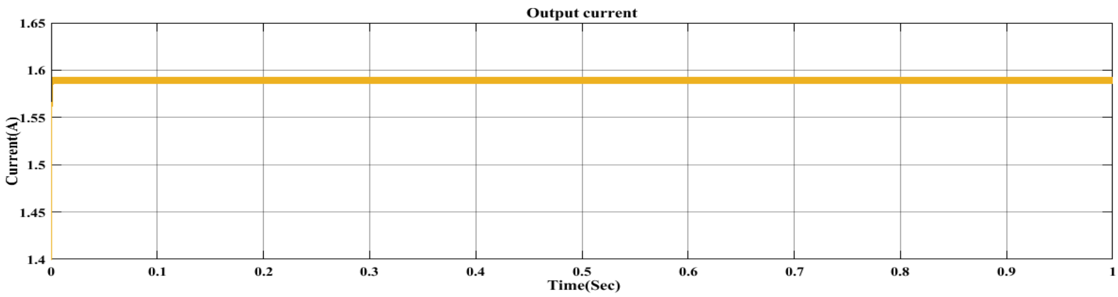


(b)

Figure 17. Simulation waveforms for (a) the output of voltage and (b) the output of current for the POSLL circuit at second model



(a)



(b)

Figure 18. Simulation waveforms for (a) the output of voltage and (b) the output of current for the POSLL circuit at third model

6. CONCLUSION

Photovoltaic models-based boost and POSLL converter circuit diagrams are approached in this paper. Where three options of solar PV models are proposed and simulated in MATLAB/Simulink with the boost circuit first and then with the POSLL circuit so as to clarify the comparison between the results to output of voltage and current for them. The tables for design parameters of the boost and POSLL converters

at three PV model accentuated a theoretical and simulation values and explain the differences between these values for the same converter, and then the differences between the two converters. These tables showed: there are some differences between theoretical and simulation results for two circuits. The POSLL circuit raises the input voltage about 3 to 4 times its original value, although duty cycle is used fewer in the POSLL circuit. The simulation waveform appeared the ripples in output of voltage and current was less with the POSLL circuit than in the boost circuit. Finally, positive output super lift Luo converter has been successfully analyzed, simulated, and improving the achievement of the photovoltaic system.

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